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SCIENCE

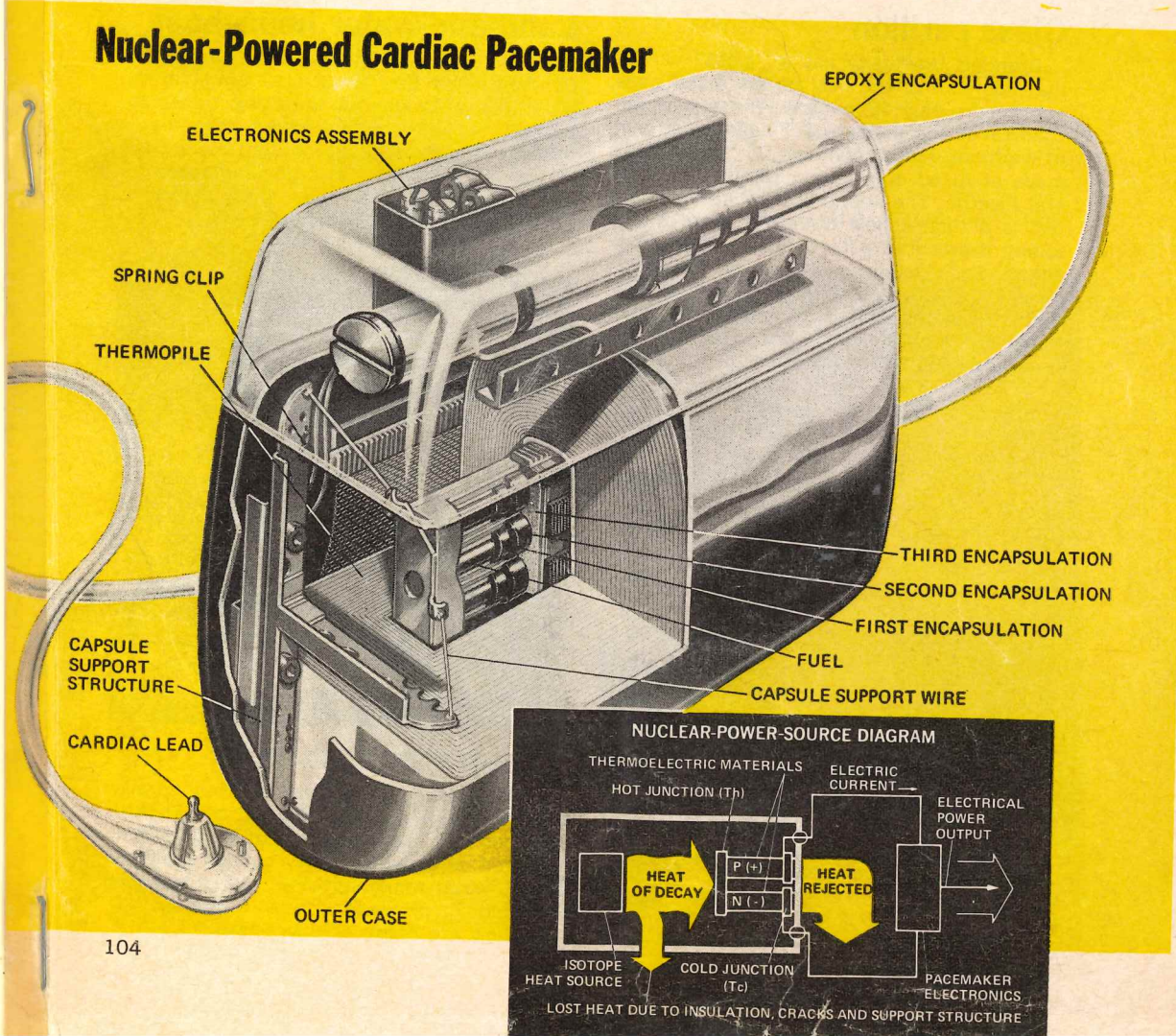
Now: Atomic Power to

To eliminate battery failure in heart

By ARTHUR S. FREESE
Illustration by Peter Trojan

ABOUT 100,000 PEOPLE owe their lives day-by-day to an electronic marvel smaller than a deck of cards and powered by tiny batteries implanted under their skin. Since its development 12 years ago, the heart pacemaker has made normal living possible for those who suffer from a malfunction of the nerves controlling the heartbeat, a rather common ailment.

Though tiny, the mercury cells that deliver a slight electric shock to the coronary muscles are relatively bulky and must be replaced about every two years. Scientists in the United States, France and Britain have been seeking a smaller, more permanent power source. In May, 1969, the first atomic pacemaker was implanted in a dog, a foxhound named Brunhilde, by National Heart and Lung Institute (NHLI) researchers. Nine days later



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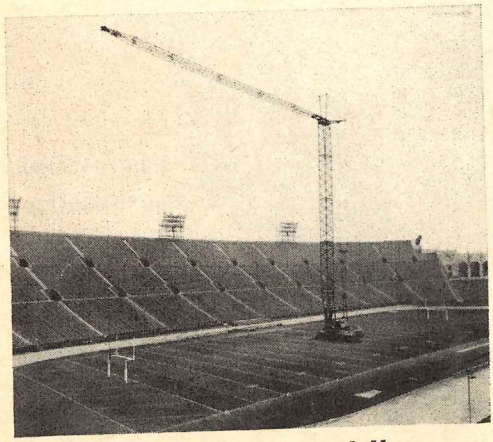
Glass carillon

Brandeis University has a "glass" carillon that sounds like the best of the metal ones, but weighs only 40 pounds. The electro-mechanical device, made by G. Finkenbeiner, Inc., of Waltham, Mass., contains 35 "glass" bells made of fused quartz manufactured by General Electric. The sound source in each glass bell is a thin, hollow thread of fused quartz tubing drawn into a foot-long, elongated-bell shape. Each bell is sealed in an evacuated glass tube with a tiny glass-tipped hammer that strikes the bell. The mechanical vibrations are electronically amplified 100,000 times and fed to loudspeakers.

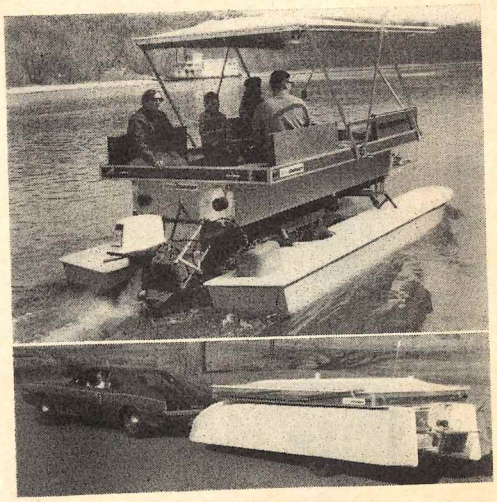


Scores from 50-yard line

It took a football field to dramatize the 150-foot reach of the Lorain Moto-Tower, a crane used in building construction. The truck-mounted tower is also 150 feet high.

Land-and-water houseboat

Powered by a 90-hp stern-drive engine, the Combo-Cruiser zips along at 20 mph in the water. Loaded onto its low-slung trailer for towing, the 23-foot houseboat is a travel trailer, complete with bathroom, kitchen (including a refrigerator) and sleeping space for five adults and one child. The maker is Ship-A-Shore Corp., Mishawaka, Ind.



Tent-trailer that floats

NaviCamper, the boating-camping-trailer sports rig, now comes in Mark II and Mark III versions. The luxurious Mark III includes such features as running lights, compass, LP-gas stove, water tank and sink. The retractable pontoons on all three versions of the 18-foot-long unit are made of fiberglass.

Keep Your Heart Beating

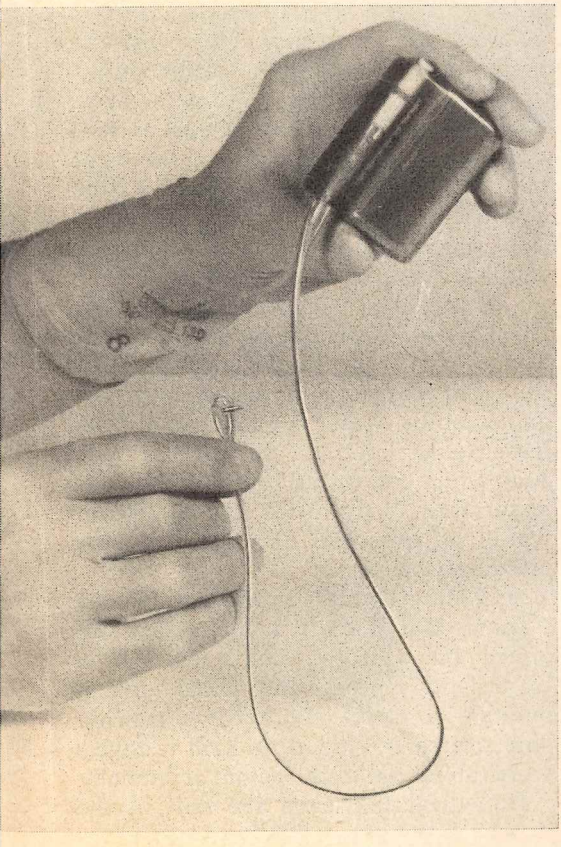
pacemakers, a tiny amount of plutonium may be the answer

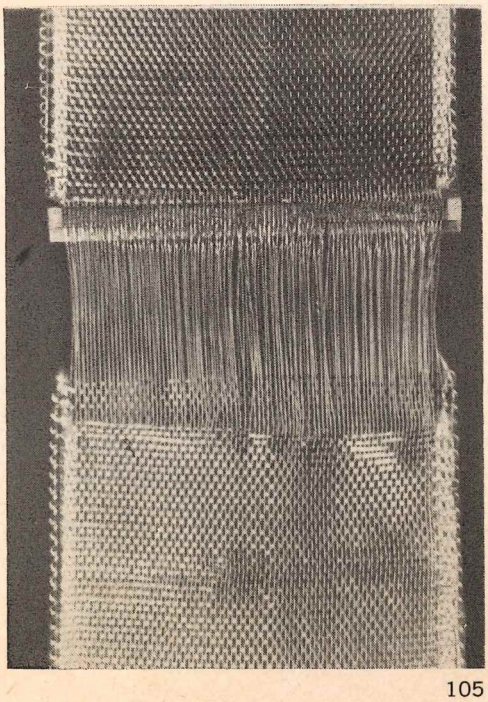
the French placed one in a deerhound. While NHLI trials with animals were still under way, the French made the first human implantation of a nuclear-powered pacemaker on April 28 of this year. The device was inserted in the chest of a 58-year-old woman. Dr. Paul Laurens, its developer, estimates that it should function without refueling for a minimum of 10 years.

The atom provides pacer power by thermoelectricity, the direct conversion of heat into electricity. In the NHLI atomic power source, three tiny rods of plutonium 238 (each triply encapsulated in tantalum-tungsten alloy, Hastelloy "C," and titanium-palladium) are the source of the heat. The plutonium gives off alpha particles, but their penetrating power is so slight that they can be stopped by a piece of paper. About 500 milligrams (less than $\frac{1}{50}$ of an ounce) of plutonium is used.

According to Stanley Seiken, chief of the Atomic Energy Commission's Isotope Power Branch, the nuclear device is at present "a handmade laboratory system. We know it works. It's now a matter of adapting the design so it can be manufactured."

Dr. Sidney Levitsky, NHLI heart surgeon responsible for implanting the nuclear pacemaker in animals, estimates the life of the device as a mini-





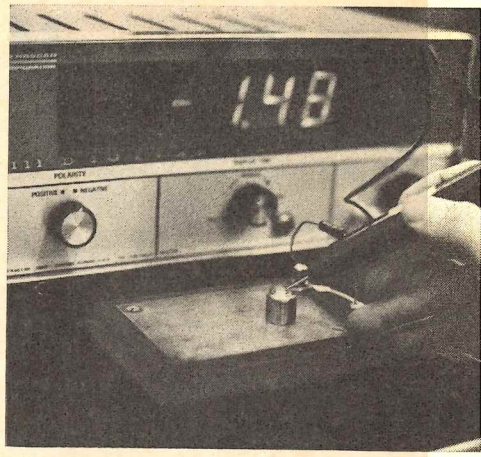
FIRST NUCLEAR-POWERED PACEMAKER (left) generates electricity from a tiny amount of plutonium 238. Heart lead (above) is normally in contact with left ventricle of the heart. The thermocouple consists of eight metallic ribbons, each containing 88 hairlike wires (right) that surround the radioisotope fuel

mum of 10 years and most probably 20. Seiken foresees the cost as probably $3000 to $5000 as compared to the $750 to $1000 for today's battery pacers. (Each set of batteries costs about $250.) But the nuclear pacer will last as long as five or more battery replacements. Each replacement also means hospitalization surgery costs and the inconvenience and risk accompanying the operation.

The American atomic pacer is about two-thirds the size of a cigaret pack and weighs only three ounces—at this stage. Its stray radiation is "no greater than that from the radium dial of some wristwatches," according to NHLI. Surrounding the plutonium rods is a copper strap with six sets of ceramic tabs, each containing 88 thermocouples. These are nine inches long, 2/1000 of an inch thick (barely thicker than a human hair). The thermocouple is made of a copper and nickel alloy wire brazed to a copper and chromium alloy wire. The thermocouples are heated at one end by the decay of the plutonium and the resultant electricity is drawn off and fed into a conventional pulse generator to operate the electronics —the same as any other pacer's.

While the French seem to have stolen the lead by having made the first human implantation, their nuclear pacemaker is, according to Medtronic, the American company that supplied the electronic components, "still in the research stage." Nevertheless, the company insists that the device is "quite superior to the AEC's and quite a bit smaller." The French pacer is an inch and a half in diameter and an inch thick. It uses 150 milligrams of plutonium, less than a third of that used in the American pacer. Its thermocouples are made of a bismuth-tellurium compound, and it's claimed that this is superior to other compounds.

Meanwhile, several institutions are pursuing research on fuel cells that would create electricity to power a pacemaker—or possibly a complete artificial heart—from human body fluids.



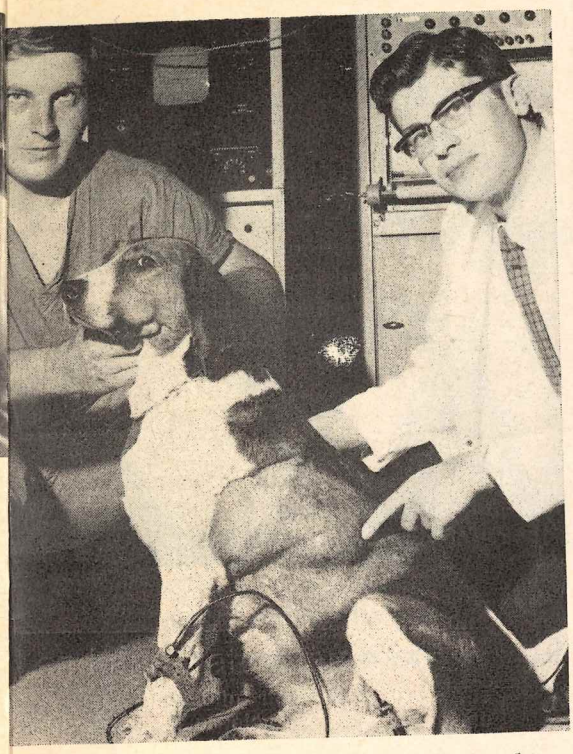
POWER FOR PRESENT-DAY PACEMAKERS comes from mercury cells; six cells form a battery that lasts an average of 18 months. Nuclear pacer implanted in dog (right) in May, 1969, is still working perfectly

Scientists have already produced small amounts of electricity by using the hydrogen from glucose and the oxygen from air. Glucose is a form of sugar found in blood serum. In one experiment a transistor radio played for three hours on the electricity produced from a pinch of sugar in a water solution. The power source consisted of two catalytic electrodes separated by a plastic membrane. Hydrogen atoms are freed from the glucose by one electrode and oxygen from the air is supplied by the other. When the hydrogen and oxygen combine, water is produced and releases electricity. In the human body such a fuel cell would draw oxygen and water from body fluids and the water would be absorbed harmlessly by the circulatory system.

At Emory University Medical School, Atlanta, Hal Warner, a biomedical engineer, has operated such a fuel cell on water and glucose and plans experiments with blood serum, the best probable source of glucose if such a device were implanted in an animal or human.

Biological fuel cells are still in the experimental stage. So, for that matter, is the nuclear pacer. Meanwhile battery-powered pacers are saving lives every day.

These electronic marvels are inserted



by a sort of life-and-death plumbing. Cardiac pacemakers sense when the heart beats normally and shut themselves off, to protect the heart and to preserve their own batteries. Yet they will promptly cut in should the heart miss even one of its 100,800 daily beats.

Your heart is essentially a hollow muscle, about the size of your clenched fist and weighs less than three-quarters of a pound. Its two upper chambers are called "atria" (plural of atrium) and its two lower—and larger—ones, "ventricles." Your blood is driven through your heart by a flowing muscular contraction (like squeezing fluid out of a balloon), starting with the topmost muscles and sweeping through at some 70 times a minute (nearly 40 million heartbeats a year).

Your heart is kept beating—and its rate determined—by a tiny lump of modified muscle at the back of the right atrium and close to its top. This is the sinoatrial node, your heart's *natural* pacemaker. It has been compared to an electric condenser which steadily builds up a charge, then periodically discharges. This electrical impulse spreads through the atria, reaching another bit of modified muscular tissue, the atrioventricular node, which passes the impulse on to the ventricular muscles. It is this electric current which your doctor records on an electrocardiogram.

Disease or surgery of the heart can damage these vital nodes, or the conduction of their signals. The ventricles may then be slowed ("heart-block") to half their normal rate, or even less, and perhaps occasionally stop. This produces faintness, dizziness, unconsciousness and even death. These fainting spells are called Adams-Stokes disease.

To get disorganized hearts back on the beam, work began on artificial pacemakers in the 1950s. First used on a temporary basis, the common early ones had their electrodes implanted directly on the heart. Dr. Seymour Furman, attending cardiothoracic surgeon at New York City's Montefiore Medical Center, recalls that in 1958 "we had reached the point where we felt that in a desperate-enough case we could try it." That year, a Montefiore patient whose life depended on cancer surgery also had Adams-Stokes disease, which seriously reduced his chances of surviving the surgery. Furman tried his pacemaker—and it worked!

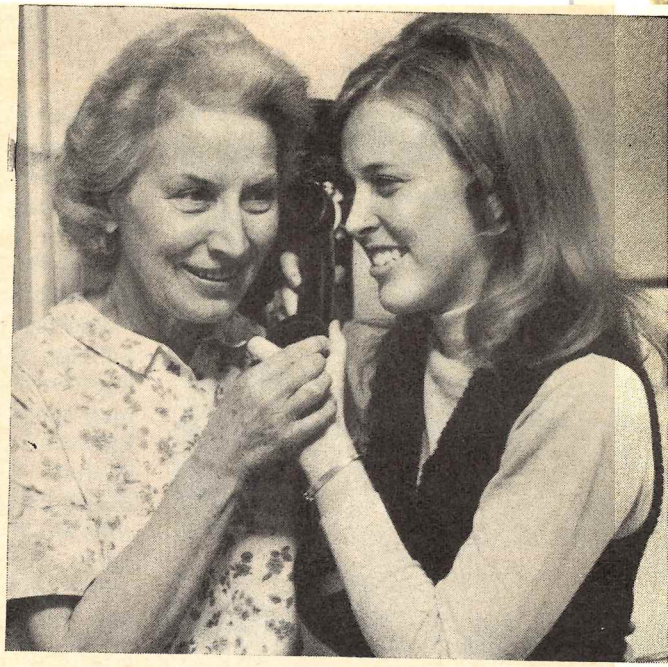
Furman and his team were the first to use a transvenous pacer, one whose electrode passes through the veins to lie in a heart chamber. But as soon as the surgery was over, surgeons removed this appliance. They next succeeded with a patient desperately ill with Adams-Stokes disease. But here the Furman team found they had a tiger by the tail—they were afraid to hang on and they couldn't let go. Every time they tried to cut off the device, the heart lost its rhythm. For three months they had to use the pacemaker. But then they knew—permanent pacing was possible.

The principle of the artificial pacemaker is simple—a painless electric shock of 3 to 6 volts can stir a heart

(Please turn to page 214)

ELECTRONICS

How to Talk to Vietnam -Free



You can phone any serviceman almost anywhere in the world via MARS and a network of volunteer ham-radio operators

By ALBERT LEE

YOU CAN ARRANGE a personal telephone conversation with any GI in Vietnam—absolutely free—thanks to a little-known organization with the unlikely name MARS. Using the free MARS service is only slightly more complicated than placing a commercial person-to-person call through to Vietnam—if you know a few of the ground rules about how the organization works.

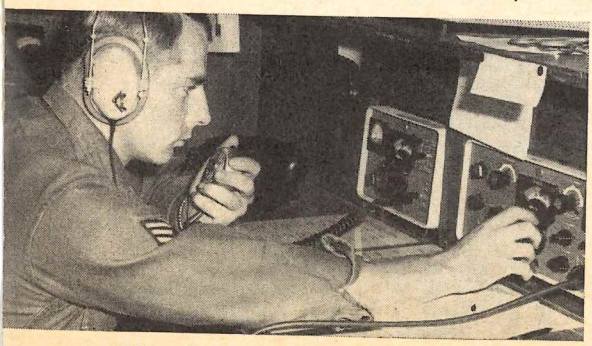
MARS (Military Affiliated Radio System) has a prime objective to act as an alternate network should regular lines of communication be blacked out during a national emergency. But since hurricanes, earthquakes and similar tragedies are infrequent, MARS members keep in practice by handling the emergencies and commonplace chatter of everyday life between servicemen and their families and friends.

MARS is a joint venture of the Armed Forces with more than 22,000 civilian ham radio operators. To be a member, a civilian must be an FCC-licensed amateur radio operator with several thousand dollars already invested in sophisticated electronic equipment.

Short of occasional government grants of surplus radio equipment, civilian members receive no compensation for their efforts. The number of calls made by members varies widely, from a New York City lawyer who places a half-dozen calls a week, to Sen. Barry Goldwater of Phoenix, Ariz., whose round-the-clock radio station completes more than 100 calls daily.

Calls are transmitted by a method known as "telephone patching." More

ARRANGING CALL from Phan Rang, Vietnam, to Jacksonville, Fla., is USAF MARS Sgt. Ted Trojanowski



TOO FAST IN FOG

(Continued from page 212)

it was a monument to the folly of driving in superhighway fog. And it was something more: *A warning of tremendous disasters to come unless drivers, officials and truckers work together to find a solution.* Ironically, the Turnpike disaster came at a time when the trucking industry was pressing hard in Washington for permission to run wider and longer trucks on the highways.

As the fog cleared, Dr. Jaffee recovered consciousness. He found himself stumbling in the grass far beyond the northbound side of the Turnpike. He saw the wreckage, the smoke and fire, the people running. He heard the screams. It was last year all over again, but this time he was in it and hurt. He slowly found his way back to the lump of metal that had been his new blue car. He probed in it, found the small box with the denture, and carefully tucked it into a pocket. Its recovery, oddly, gave him comfort. ★★★

ATOMIC POWER FOR YOUR HEART

(Continued from page 107)

to a normal "beat." Electric pulses produce the necessary 70 or so heartbeats a minute by adding a pulse generator to a power source—truly a miracle in a battery.

There are two types of pacers—myocardial and transvenous. The *myocardial,* rapidly losing favor, requires major chest surgery to expose the heart so the surgeon can sew the electrodes to its surface. Power source and pulse generator are buried under the skin nearby. This pacer is particularly useful in children whose growth will stretch and strain the electrode.

Often using only a local anesthetic and working at the bedside, the heart surgeon can insert a *transvenous* pacer by making an incision in the armpit, neck or abdomen. He then locates a large vein and snakes the pacer's electrode through the veins to the heart. The power source most commonly used today is a set of five or six mercury batteries (each little more than a half-inch in diameter and less than a half-ounce), connected in series.

Pacers work essentially in two ways—at a fixed rate or "on demand." The fixed-rate pacer, also losing favor, delivers its pulse automatically at a set rate (usually about 70 a minute). However if the heart should suddenly beat by itself at the exact moment of the pacer's shock, the double impulse can throw the heart muscles into runaway disorganized contractions and lead to major problems. For this reason "demand" pacers were developed.

The demand pacer is designed to utilize the heart electrode as both the stimulating and the sensing device. If the heart has a normal beat, the electrical impulse in the muscle is sufficient to inhibit the pulse generators and the pacer will rest until the normal heartbeat stops. Even a single missed beat, however, will bring the pacer back into action!

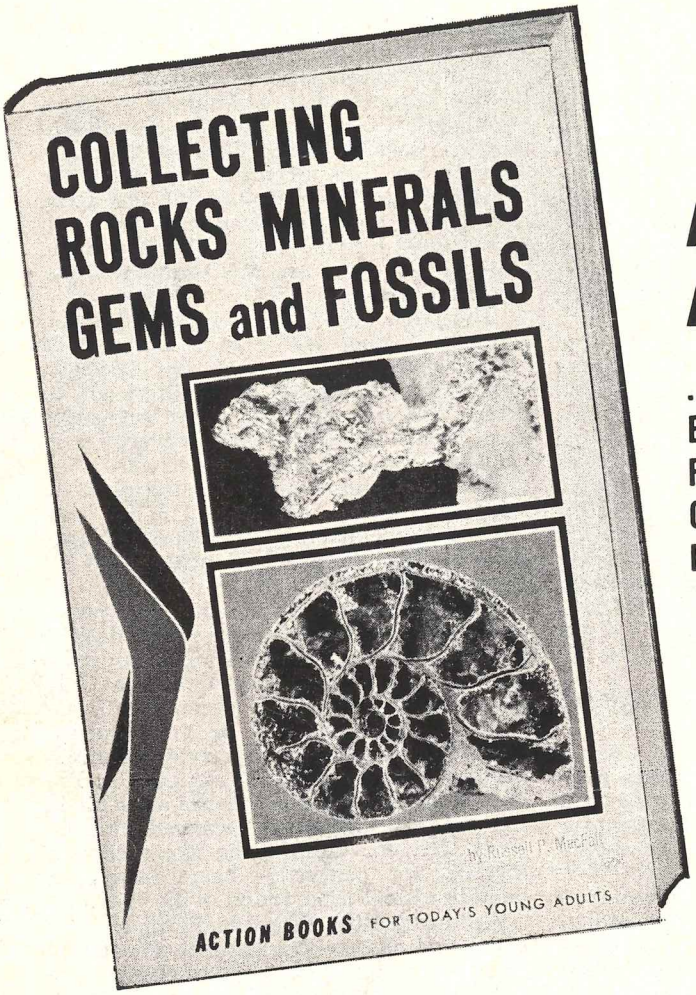
The pulse generators emit a 3 to 6-volt impulse lasting for 1 to 2 milliseconds (thousandths of a second) and taking a tenth to a thousandth of a millisecond to reach full intensity. The heart electrodes may be helical coils of metal covered with silastic: platinum-iridium, stainless steel, gold or platinum-plated stainless steel, or even Elgiloy (chromium, nickel, iron and other metals) at a thickness of about two human hairs (0.006 inches) are all used.

What effect has the wearing of a pacemaker on its owner? How much does it limit his activity? At what ages can it be used? U.S. Supreme Court Justice William O. Douglas—whose pacemaker is almost always mentioned in stories about him—is past 70 and is an avid mountain climber. At the opposite extreme, is Elliott Wilson: Only a few hours after birth, his electrocardiogram showed heart-block. By his tenth day he was receiving digitalis for congestive heart failure, a condition more often found in the aged.

At four months, Elliott had a temporary pacer and shortly thereafter a permanent junior-size one. There are a considerable number of children like Elliott who attend regular school, enjoy unrestricted activities, even go to camp. At Yale University, doctors have successfully implanted an extra six or eight inches of electrode coil enclosed in a Teflon envelope—it pays out as the child grows.

There is Will Gray, an active 40-year-old executive who works and travels at high speed. His first pacer was an early, and relatively primitive, myocardial one installed in 1961. It failed, and Furman replaced it with a transvenous model. When the batteries recently ran down, Gray entered the hospital on a Thursday afternoon. His battery was replaced on Friday, and he was home catching up on work by Saturday. Incidentally, Will is not a guy to tangle with—he takes jujitsu lessons!

While you're certainly better off if you never need a pacer, if you do, this marvelous electronic device can save your life! And when the atomic pacemaker is perfected and available, you may never have to give it another thought. ★★★



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Atomic-powered dog

Goldie, a labrador, frisks about while her heart, 100 times a minute, gets an electric shock from a pacemaker. Its atomic battery (lower right, in comparison with a cigaret) is powered by a pellet of plutonium. The pacemaker was inserted at London's National Heart Hospital. (See *Atomic Power to Keep Your Heart Beating*, page 104, Sept. *PM*.)

OCTOBER 1970

Popular Mechanics p. 119

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